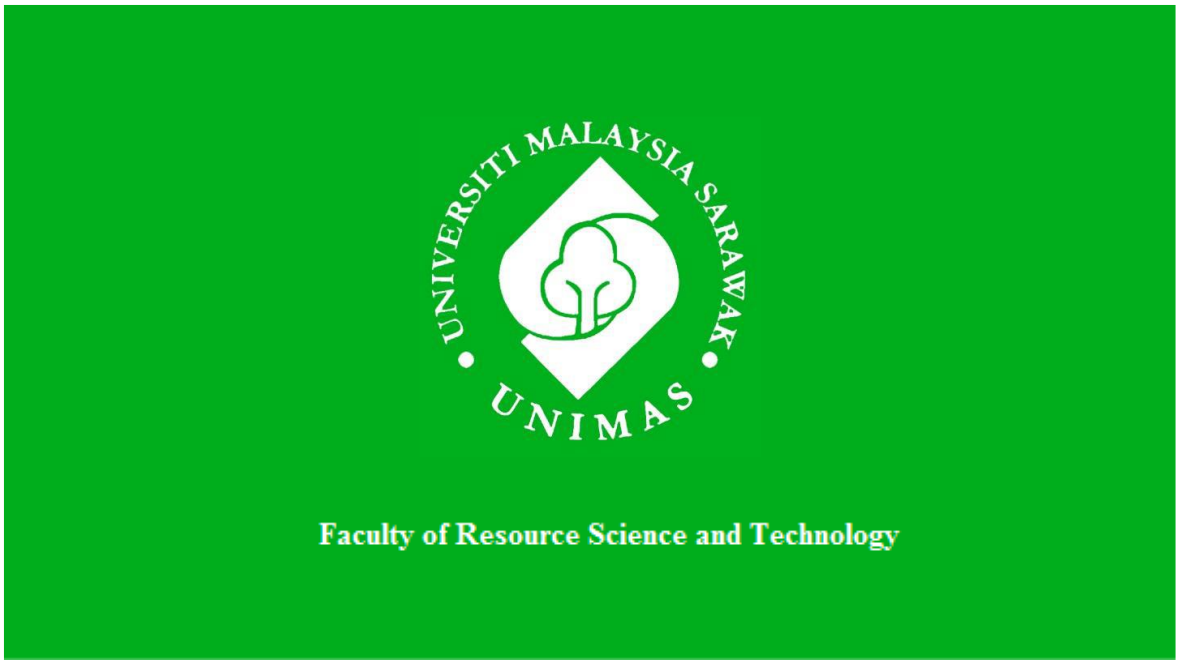

Estimation on Soil Organic Carbon following Enrichment Planting at Reforestation Sites in Gunung Apeng National Park, Sarawak

Mohd Masrinizam Bin Iskandar

(47689)

Bachelor of Science with Honours
(Plant Resource Science and Management)
2017

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(Name of the supervisor)

Dr. Mohd. Effendi bin Wasli
Lecturer
Faculty of Resource Science and Technology
UNIVERSITI MALAYSIA SARAWAK
94300 Kota Samarahan

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Lecturer
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UNIVERSITI MALAYSIA SARAWAK
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Estimation on Soil Organic Carbon following Enrichment Planting at Reforestation Sites in Gunung Apeng National Park, Sarawak

Mohd Masrinizam Bin Iskandar

This thesis is submitted in partial fulfillment of the requirement for the degree of the Bachelor of Science with Honours

(Plant Resource Science and Management)

Supervisor: Dr Mohd Effendi Bin Wasli

Department of Plant Science and Environmental Ecology

Faculty of Resource Science and Technology

Universiti Malaysia Sarawak

2017

APPROVAL SHEET

Name of candidate : Mohd Masrinizam Bin Iskandar

Title of dissertation : Estimation on Soil Organic Carbon following Enrichment Planting at Reforestation Sites in Gunung Apeng National Park, Sarawak

_____

Dr. Mohd. Effendi Wasli
Supervisor

_____

Dr. Freddy Yeo Kuok San
Coordinator
Plant Resource Science and Management Programme
Department of Plant Science and Environmental Ecology
Faculty of Resource Science and Technology

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(Mohd Masrinizam Bin Iskandar)

Plant Resource Science and Management Programme

Department of Plant Science and Environmental Ecology

Faculty of Resources Science and Technology

Universiti Malaysia Sarawak

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Estimation on Soil Organic Carbon following Enrichment Planting at Reforestation Sites in Gunung Apeng National Park, Sarawak

Mohd Masrinizam Bin Iskandar

Plant Resource Science and Management
Department of Plant Science and Environmental Ecology
Universiti Malaysia Sarawak

ABSTRACT

Soil organic carbon (SOC) is one of the factors that influence the growth development of the trees and it is important to maintain the soil fertility, nutrient cycling, soil structures and soil water holding capacity. A study was conducted in Gunung Apeng National Park, Sarawak in order to quantify the differences in soil organic carbon as well as other relevant soil properties following enrichment planting. Reforestation sites which were planted with *Dryobalanops beccarii* by line planting system were selected in this study. Study sites were established at young reforestation site (year 2014; DB14), old reforestation site (year 2006; DB06), secondary forest (SF) and disturbed site (DS). Undisturbed and composite soil samples were collected from several random points at the depth of 0-10 cm, 10-20 cm and 20-30 cm, respectively. The findings indicated that the average soil total carbon in secondary forest was significantly higher as compared to all the other study sites. However, in terms of the mass of soil organic carbon estimation, DB06 depicted the highest value with 1266.45 g m^{-2} followed by DB14 site with 1117.26 g m^{-2} at the depth of 0-30 cm, respectively. The estimated average annual changes in SOC at DB06 site and SF site were 3.45 Mg C ha^{-1} yr^{-1} and 2.05 Mg C ha^{-1} yr^{-1}. The estimate of the average annual changes in SOC at DB06 and SF sites were almost similar since the soils were near SOC equilibrium. Differences were observed in several soil properties but strong correlations with SOC content were only observed for bulk density. In conclusion, these results indicate that within 2 decades of tree planting, there was significantly greater SOC in soil and reach SOC equilibrium based on SOC average annual changes.

Keywords: reforestation, soil organic carbon, soil psychochemical properties, *Dryobalanops beccarii,* Sarawak

ABSTRAK

Karbon organik tanah (SOC) adalah salah satu faktor yang mempengaruhi tumbesaran pokok dan penting dalam mengekalkan kesuburan tanah, kitaran nutrien, struktur tanah dan kapsiti tanah menahan air. Satu kajian telah dijalankaan di Gunung Apeng National Park, Sarawak untuk menganggarkan perbezaan karbon organik tanah dan sifat tanah yang berkenaan selepas tanaman mengaya. Plot penanaman semula yang telah ditanam dengan Dryobalanops beccarii secara tanaman baris telah dipillih untuk kajian ini. Plot kajian telah ditubuhkan di plot penanaman semula yang baharu (tahun 2014; DB14), plot penanaman semula yang lama (tahun 2006; DB06), hutan sekunder dan plot tanah terganggu. Sampel tanah komposit dan yang tidak terganggu telah diambil pada kedalaman 0-10 cm, 10-20 cm dan 20-30 cm. Kajian menunjukkan purata kadar tanah karbon di hutan sekunder lebih tinggi daripada plot kajian yang lain. Walau bagaimanapun, berat karbon organik tanah di plot DB06 menunjukkan kadar yang tertinggi iaitu 1266.45 g m^{-2} di ikuti plot DB14 dengan 1117.26 g m^{-2} pada 0-30 cm kedalaman tanah. Anggaran purata perubahan tahunan bagi SOC pada plot DB06 adalah 3.45 Mg C ha^{-1} yr^{-1} manakala plot SF adalah 2.05 Mg C ha^{-1} yr^{-1}. Anggaran purata perubahan tahunan SOC di plot DB06 dan SF menunjukkan hampir sama kerana telah mencapai keseimbangan kadar SOC pada tanah. Perbezaan di kaji pada sifat tanah yang berkaitan tetapi kolerasi tinggi hanya terdapat pada bulk density dengan SOC. Kesimpulannya, hasil kajian menunjukkan penanaman pokok dalam tempoh 20 tahun akan meningkatkan dan mencapai tahap keseimbangan SOC di dalam tanah berdasarkan anggaran perubahan SOC tahunan.

Kata kunci: penanaman semula, karbon organic tanah, fiizikokimia tanah, *Dryobalanops beccarii,* Sarawak

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List of Abbreviations

TRF	Tropical rainforests
FAO	Food and Agricultural Organization's
CLASlite	Carnegie Landsat Analysis System-lite
PFE	Permanent Forest Estate
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
TC	Total Carbon
TN	Total Nitrogen
BD	Bulk Density
ODP	One Drop Penetrability
cm	centimetre
m	metre

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1.0 Introduction

Soils contain carbon in organic and inorganic forms such as oxidized carbon and non-oxidized carbon. Total carbon can be referred as the sum of two forms of carbon. Soil organic carbon (SOC) is the carbon occurring in the soil organic matter (SOM), which 58 percent of SOM mass (Corsi et al., 2012). According to Corsi et al. (2012), SOM is used to describe the organic constituents in the soil: tissues from dead plants and animals, materials less than 2 mm in size and soil organisms in various stages of decomposition. Reforestation are often considered as most important practices for sequestrating carbon (C) as a component of climate change mitigation strategies. Forest ecosystems important to improve soil quality of degraded or marginal lands by reducing soil disturbance and providing perennial ground cover, also providing numerous ecosystem services

Tropical rainforest (TRF) known as the most complicated ecosystem with high variability in their environmental conditions (Konishi et al., 2006). Whitmore (1998) and Inoue et al. (1994) reported that tropical rainforest has the highest amount of species compared to other forest around the world. Tropical rainforest in Southeast Asia are globally significant and richest distinct forest in the world with enormous proportion of the world's biodiversity (Myers et al., 2000). These forests provide significant ecosystem benefits including fresh water management, pollination services and soil protection (Kettle, 2009).

However, tropical rainforest in Southeast Asia rapidly degraded by commercial logging, shifting cultivation, industrialization, ecological disturbances like erosion and other factors which lead to deforestation in tropical regions (Indrioko et al., 2016; Perumal et al., 2015). According to Okamura et al. (1999) human activities such as logging, land clearing for crop plantation and forest fire has been identified as one of the major causes of degradation of tropical rainforest. These deforestation activities resulting loss in timber and

non-timber forest products (Lamb et al., 2005). In soil ecosystem, deforestation activities lead to significant changes in both physical and chemical characteristics and biochemical cycles (Maloney et al., 2007). Deforestation also can lead to deterioration of soil fertility by decrease in soil organic matter due to disturbance of nutrient cycling process (Heryati et al., 2011). Land-use changes strongly affect the soil carbon storage like cropland conversion to forest will result in partial to complete recovery in soil carbon (Guo and Gifford 2002; Post and Kwon 2000). According to Lugo and Brown (1993), soil organic carbon is a large reservoir that can act as a sink or source for atmospheric carbon dioxide (CO_2). Therefore, a relatively small change in the soil carbon pool can precipitate a large effect on the global carbon cycle.

There are many ways to encounter the issues with regards to deforestation, one of the best ways is by establishing reforestation programmes through enrichment planting. According to ITTO (2002), reforestation is a re-establishment of tree after some disturbance. Reforestation helps in restoring soil fertility and increase the productivity of poor vegetation seedling. Reforestation is very important not only for wood demands but also to recover degraded soil (Parotta, 1992). Heryati et al. (2011) mentioned that, establishment of reforestation activities can turn forest to more productive area by restoring soil fertility and productivity, reduce soil erosion, and providing nutrient in soils. Reforestation activities not only ensure forest ecosystem stability but may also improve the structure and function of forest along with soil fertility, nutrient cycle and production of organic matter.

Therefore, soils perform vital function and important element for plant growth. According to Karam et al. (2012), plants growth are influenced by soil compaction, relation, aeration, and soil temperature. Furthermore, soils help in maintaining biological and biochemical processes for nutrient cycling. Reducing soil disturbance and provide various ecosystem services by continual ground cover can improve soil fertility of degraded soil in

forest ecosystem (Van Schoenholtz et al. 2000; Boussougou et al. 2010). According to Lal (2005), reforestation can boost terrestrial carbon by humification and storage in soil organic carbon (SOC).

1.1 Problem Statements

Soil organic carbon (SOC) plays an important role in both forest ecosystem and agricultural activities which control soil fertility and plant production (Tiessen et al., 1994). According to Anderson, (1987); Gale and Cambardella, (2000) the rate of total organic input to the soil including soil organic carbon (SOC) of forest system were much higher than cropped or grassland systems because of aboveground litter decomposition. Sauer et al. (2002) reported that, soil disturbance such as ripping, mounding, and cultivation during site preparation for leads to low carbon input and one of the main factor that lead to decrease of SOC during tree establishment activities especially at the first 5 years after tree planting. Based on previous study, among the factors influenced the amount of SOC are tree species, soil properties, climate and previous land use activities. Understanding and study on the changes of soil organic carbon following artificial planting is still limited, especially in the humid tropics of Malaysia which this reforestation activities may restore soil carbon lost during land-use change in short period of time. In addition, only few information was documented and published on the effect of SOC under enrichment planting, particularly in Sarawak. Therefore, this study was conducted to quantify the differences SOC under enrichment planting in Sarawak.

1.3 Objective

The objective of this study was to quantify the differences in soil organic carbon as well as other relevant soil properties following enrichment planting by analysing the soil samples from reforestation sites, secondary forest and disturbed site.

2.0 Literature Review

2.1 Current Status of Tropical Rainforest in Southeast Asia

Southeast Asia is one of the largest tropical forests and the entire region was covered by forest. In Malaysia, 19.54 million hectares of land area are still covered by forest with 9.24 million hectares total forest area in Sarawak (Shamsudin, 2006). According to Forest Department (2009), 80 percent of land area in Sarawak are still covered by both primary and secondary forest. Secondary forest can be defined as ecological systems developing from clearing forest for shifting cultivation. Based on Lanly (1982), secondary forest exists in both types of forest formation which are forest and open forests.

In Borneo, forest canopy is broadly dominated by large trees and mostly from the family of Dipterocarpaceae. Dipterocarp trees have been most valuable source of timber in Borneo region. Meanwhile, several species are extremely endangered because of over-logging, wide-ranging illegal cutting and clearing natural habitat for agriculture. Deforestation for purpose of oil palm planting are one of the main crisis in Borneo. In Kalimantan, Indonesia, large protected area is being logged and declined by more than 56% between 1985 and 2001 (Curran et al., 2004; WWF Globe, 2013).

Nowadays, tropical rainforest has undergone huge depletion due to high demand for timber. Thus, most areas of the rainforest have been cleared for timber and agricultural purpose. Reforestation is one of the ways to restore forest. Reforestation can be defined as to re-establishing the original forest ecosystem that was present before deforestation occurred. According to Kanowski and Catterall (2007), reforestation programme through two main phase which are an early establishment phase and continual building phase. Based on Parotta (1992), establishing that plantations of native or exotic species adapted to stressful conditions characteristics of degraded lands can reverse the degradation process.

2.2 Reforestation Efforts in Malaysia

The reforestation of forest is important for forest ecosystem which restore soil fertility and soil organic matter of degraded area including increase productivity of poor vegetation product. In Malaysia, Brazil, Chile, and China, the application of restoring forest based on ecological studies were successful (Miyawaki, 1999). In Sarawak, the reforestation activities have been carried out at various areas such as Sampadi Forest Reserve (Perumal et al., 2015), Sabal Forest Reserve, Niah Forest Reserve and Bakam Experimental Reserve (Sakurai et al., 2006) and Gunung Apeng National Park (Wasli et al., 2014)

Enrichment planting was one of the effective methods in reforesting degraded forest. According to Paquette et al. (2006), enrichment planting important for introduce commercial species in degraded forest. In addition, Truax et al. (2006), stated that enrichment planting important for convert even-aged plantation monocultures into mixed forest stand with more complex system. Besides that, enrichment planting increase tree species richness. Based on Duncan & Chapman (2003), enrichment planting had a high probability of survival on performance of tree but this method required high cost of maintenance and field labor.

In 1979, Forest Department Sarawak took a step and started their reforestation Programme. The objective of the programme was to reforest shifting cultivation and degraded areas within permanent forest estates to productive forest as well as to achieve its sustainable forest production role in the future (Jiwan and Alek, 1999). The planted species for reforestation practices in Malaysia *are Shorea macrophylla, Shorea pinanga, and Dryobalanops* spp such as *Dryobalanops beccarii, Dryobalanops aromatica* and *Dryobalanops lanceolata.*

2.3 Soil Carbon Stock after Deforestation

According to Food and Agriculture Organization's (FAO) stated that 62.3% of Malaysia is forested and 18.7% is categorized as primary forest. They also claimed that there are about 1 807 000 hectares of planted forest in Malaysia. In Sarawak alone, there are 9.89 million hectares of existing forest types including PFE, national and wildlife parks, and state land forest (Krishnapillay et al., 2007). According to FAO (2009), deforestation can be defined as the transformation of forest to another land use or the long term loss of the tree canopy cover below the minimum 10 percent threshold. Besides uncontrolled logging, forest in East Malaysia were also lost because of shifting cultivation by the natives. Based on Gilbert (1980), logging activities for timber and forest clearance for agricultural land one of the major causes of forest destruction.

Deforestation in Malaysia has becoming more serious as more forest areas have been cleared for various purposes such as for agriculture activities, mining, and urban development. Areas that has been degraded due to mining activities caused only a small number of plant species to grow and this happened because of the poor soil fertility in the area. This might be due to the changes in physical properties of the soil due to the mining activities (Krishnapillay, 2007). Uncontrolled and unsustainable logging activities has contributed to even more degraded forest areas. Yong et al. (2014) said that University of Maryland has revealed that Malaysia is on ninth place in world's highest rate of forest loss. From year 2000 until 2012, Malaysia has lost 14.4% of its forest areas. They also stated that in year 2010 until 2012, there were 4.72 million hectares of forest loss in Malaysia. Previous research done by University of Tasmania, University of Papua New Guinea, and the Carnegie Institution for Science showed that by using a high resolution satellite imaging of the Carnegie Landsat Analysis System-lite (CLASlite), there were more than 80% of forest affected by logging activities in Malaysia Borneo forests.

According to Guo and Grifford (2002), soil carbon storage strongly influenced by land-use changes. Uhl et al, (1998), stated that, the potential of the abandoned land to recover and maintain the roles of land is dependent on the intensity of previous land use. After deforestation activities, soil carbon decreases significantly and it is expected to recover after several years in the tropics. According to Yonekura et al (2010), top soil carbon decrease temporarily after deforestation and during the initial stage of grassland growth due to enhance decomposition of SOM in bare soil and wildfires. Generally, deforestation not only lead to global warming, hence, this activities also lead to substantial loses of carbon from vegetation and soils. The deforestation activities caused a rapid decrease of biomass carbon due to loss of carbon from the soils. SOC loss after deforestation were affected by climate factor, particularly moisture condition, and temperature. The loss of SOC may increase gradually due to increase of temperature and decrease of soil moisture regimes which lead to increase the decomposition rates.

2.4 General information on *Dryobalanops beccarii* (Dyer) in Sarawak

In tropical rainforest (TRF), there are several timber families such as Dipterocarpaceae, Fabaceae, Burseraceae, Lamiaceae, and Meliaceae. Dipterocarpaceae was most popular trees in tropics among the other timber families of plants. According to Poore (1989), Dipterocarpaceae family plays important role in tropics and economics of Asian forest. In addition, Dipterocarpaceae family sources of various minor products on which most forest dwellers are directly dependent for it survival. In addition, the family Dipterocarpaceae is well known for timber values because this timber family plants have good quality of lumber (Pusttaswamy et al., 2010).

Dryobalanops commonly known as Kapur in Malaysia. One of the famous *Dryobalanops* species in Malaysia is *Dryobalanops beccarii*. This species is also known as kapur bukit by the local people in Sarawak since it grows on hill. *Dryobalanops beccarii* usually can be found on shallow leached soils between both sandstone and shale in mixed dipterocarp forest (Dyer, 1984). In addition, *Dryobalanops beccarii* can grow up to 40-65 metre in height and more than 1 metre in diameter (Chua and Saw, 2003). Malaysian Grading Rules recognised *Dryobalanops beccarii* as Medium Hardwood and one of those valuable timber spieces (Harwood, 1998). This timber species usually used for construction, manufacturing of furniture, and the sawn wood are also can be used for firewood. One of the special potential characteristics for *Dryobalanops beccarii* is fast growing plant thus this timber species has been selected in large scale forest plantation. Phua et al. (2007), stated that this tree species was selected for restoration of peat swamp vegetation that was destroyed by fires at Klias Forest Reserve. In Klias Forest Reserve, this tree species was planted and the survival percentage was about 83.1% thus this indicated that there was no significance effect of drainage on its growth. In addition, Chua and Saw (2003), reported that *Dryobalanops beccarii* grown on ridges in several booths in the Panti Forest Reserve, Johor.

According to Wasli et al. (2014), Sarawak Forest Department and other international agencies have implemented a reforestation on the shifting cultivation area which have been abandoned to re-stablish the tropical rainforest by planting some types of tree species including *Dryobalanops beccarii* in Gunung Apeng Forest Reserve. Based on Chua and Saw (2003), *Dryobalanops beccarii* have a wide range of distribution from Peninsular Malaysia to Borneo land.

2.5 General Soil Properties in Southeast Asia

Soil organic matter (SOM) levels in any agroecosystem and forest ecosystem are regulated by the interaction of factors that determine formation and promote its decomposition (Fernandes et al., 1997). Primary plant production and soil biological activity are two main biological processes governing inputs and outputs of SOM in the system, and the equilibrium between both determines the SOM cycling dynamics (Six et al., 2002). According to Covaleda et al., (2000), SOM is an important for sustainability in forest systems, acting as a key element in the soil quality. Soil is an important component of its environment. According to Fisher et al., (2000), soil important for medium for growth of plant, provide physical support, moisture, and nutrient, including serves as home for variable organisms. Forest are rich in organic matter that useful for plant growth. According to FAO (1998), high accumulation of organic matter on the surface of soil and active microorganisms was influenced by decomposition of organic matter such as litter and animal manure.

Any disturbance that occur during reforestation will result in nutrient limitation which may affect the forest recovery and soil carbon accumulation (Marin-Spiotta et al., 2009). According to Sanchez et al (2003), Juo and Franzlueebber (2003), most soils in tropical region are infertile and once the natural forest been cleared, nutrients can be rapidly loss consequently leading to longer forest recovery time.

Pritchett and Fisher (1987) stated that, soil in tropical rainforest of Southeast Asia mostly are acidic and the type of soil commonly Oxisols, Ultisols, and Spodosols. Oxisols and Ultisols types of soil have high acidity and lack of phosphorus, potassium, calcium, nitrogen, magnesium and various micronutrient. Both of this soil have high leaching potential because of low in effective cation exchange capacity but generally high in